GUJARAT TECHNOLOGICAL UNIVERSITY

ENVIRONMENTAL SCIENCE AND TECHNOLOGY (35)
INTRODUCTION TO HEAT TRANSFER
SUBJECT CODE: 2153502
B.E. 5thSEMESTER

Type of course: Environmental Science & Technology

Prerequisite: A good understanding regarding basic modes of heat transfer viz conduction, convection and radiation with governing laws underlying these heat transport mechanisms. Mathematical background is also essential in this respect.

Rationale: Heat transfer is a necessary process in virtually all forms of energy generation and use; from coal fired to nuclear power stations, from automobile engines to rocket motors, from refrigerating cold stores to air conditioning space vehicles. This subject is intended to make students aware about mechanisms involved in heat transfer process in many of aforementioned applications. This ultimately will enable the students to design the equipments for heat process viz, shell and tube heat exchangers, condensers.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks						Total Marks
L	T	P	C	Theory Marks			Practical Marks			
				ESE (E)	PA (M)		ESE (V)		PA (I)	
					PA	ALA	ESE	OEP		
3	1	2	6	70	20	10	20	10	20	150

Content:

Sr. No.	Topic	Teaching Hours	Module Weightage (%)
1.	**Basic Concepts**: Overview of applications of heat transfer in different fields of engineering, modes of heat transfer- conduction, convection and radiation, heat transfer with and without change of phase. **Conduction:** Mechanism of heat conduction, Fourier's law, thermal conductivity of solids, liquids and gases, effect of temperature on thermal conductivity, General heat conduction equation in Cartesian coordinates, Boundary conditions, Formulation of heat transfer problems without generation of heat, Conduction through systems of constant thermal conductivity :- conduction through plane, cylindrical and spherical wall, combined boundary condition systems (conduction-convection systems), conduction through composite slab, cylindrical and spherical shells. Electrical analogy to heat flow, Critical and Optimum thickness of Insulation. **Unsteady State heat Conduction:** Analysis of transient heat flow with negligible internal resistance-lumped capacity analysis, concept of Biot Modulus and Fourier number	9	20
2.	**Convection:** Mechanism, thermal and velocity boundary layers, boundary layer thickness, relationship between hydrodynamic and thermal boundary	9	30

	layer thickness for flow over flat plates, the convective heat transfer coefficient, reference temperatures, thermal boundary layers for the cases of flow over a flat plate and flow through pipe, dimensionless numbers in heat transfer and their significance. **Forced Convection:** General methods for estimation of convection heat transfer coefficient, Correlation equations for heat transfer in laminar and turbulent flow for external and internal flows for constant heat flux and wall temperature conditions- flow in a circular tube Analogy between momentum and heat transfer: Development of Reynold's and Prandtl analogy. Overview of Colburn and Von-Karman analogies (No derivation required). Comparison of different analogy expressions. **Natural Convection:** Dimensional analysis, natural convection from vertical and horizontal surfaces under laminar and turbulent conditions for plates, cylinders, physical significance of Grashoff and Rayleigh numbers. **Heat transfer by radiation:** Introduction- theories of radiation, electromagnetic spectrum, thermal radiation, spectral emissive power, surface emission- total emissive power, emissivity. Radiative properties, Emission, irradiation, absorptivity, reflectivity and transmissitivity. Concept of black and grey body, radiation intensity, Laws of black body radiation, non-black surfaces- Grey, white and real surface, Lambert's cosine law, radiation between black surfaces and gray surfaces		
3.	**Heat Exchangers:** Classification of heat exchangers: Classification according to transfer processes, number of passes, surface compactness, construction features, flow arrangements, heat transfer mechanisms. Shell and tube heat exchanger, fouling, concept of overall heat transfer coefficient, LMTD, correction factor for LMTD, Sizing and rating problem using LMTD method in parallel flow, counter flow exchanger, cross flow and multi-pass heat exchangers, Temperature – distance plots for different flow arrangements in single and multi-pass heat exchangers. Determination of area, length, number of tubes required for a given duty in different configurations using LMTD method of analysis. Concept of Effectiveness- NTU method, definition of effectiveness, effectiveness NTU relations for single pass exchangers in counter-flow and parallel flow configurations. Double pipe heat exchangers: - construction, various steps for the design of double pipe heat exchangers. Plate and spiral heat exchangers, Condensers.	9	30
4.	**Boiling and Condensation:** Pool boiling - Boiling curve, hysteresis in the boiling curve, mechanism of nucleate boiling, Forced convection boiling - Brief over view of internal forced convection boiling. Condensation: Physical mechanisms, types of condensation, factors affecting condensation. **Evaporation:** Principle of Evaporation, types of evaporators- their construction and operation, Natural circulation evaporators, short tube vertical or calendria type evaporators, basket type vertical evaporators, long tube vertical evaporators, forced circulation evaporators, falling film evaporators, climbing or rising film evaporators, agitated thin film evaporators, the plate evaporator. Single effect and multiple effect evaporators, Performance of evaporators, capacity and economy of evaporators, Overall heat transfer coefficient, effect of liquid head and boiling point elevation. Material and energy balances for single effect evaporator and the calculations on single effect evaporator. Multiple effect evaporators, Energy Balance.	9	20

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
21%	**23%**	**20%**	**18%**	**18%**	**-**

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. Özisik M. N, "Heat Transfer—A Basic Approach", McGraw-Hill.
2. Binay. K. Dutta, "Heat Transfer Principles and applications" Prentice Hall of India
3. Kern D Q, Process Heat Transfer, McGraw Hill Book Co. (1997).
4. Coulson J M and Richardson J F, Chemical Engineering Volume 1, Pergamon Press (1999).
5. Incropera F. P. and DeWitt D. P, "Introduction to Heat Transfer". John Wiley & Sons.
6. Holman J. P, "Heat Transfer", McGrawHill.
7. Sachdeva R.C, "Fundamentals of Engineering Heat and Mass transfer", New Age International, India
8. Rao Y.V.C, "Heat Transfer", University Press, India
9. Cengel A. Yunnus. "Heat Transfer – A Practical Approach", McGraw Hill
10. Geankopolis C J, Transport Processes and Separation Process Principles, Prentice Hall of India, 4th Edition, Eastern Economy Edition (2004)
11. Kothandaraman C.P, "Heat and Mass Transfer Data Book" New Age International, India
12. Ramesh K. Shah and Dušan P. Sekulic, Fundamentals of Heat Exchanger Design, John Wiley & Sons, Inc. 2003

Course Outcome: After learning this course the students can:

1. Properly identify important heat transfer modes in a physical system
2. Analyze heat conduction equation based on boundary conditions for any well posed conduction heat transfer problem
3. Suitably perform sizing and rating problem and can estimate pressure drop for a given design system working on heat transfer principles.

List of Experiments:

1. Determination of thermal conductivity of solids
2. Determination of heat transfer coefficient by natural convection
3. Determination of heat transfer coefficient by forced convection: Determination of Forced convection heat transfer coefficients for flow of fluids through heated ducts
4. Determination of overall heat transfer coefficient for counter flow in laminar regime in double pipe heat exchanger
5. Determination of overall heat transfer coefficient and efficiency in shell and tube heat exchanger

6. Heat Transfer in Composite walls- Determination of effective thermal conductivity and overall resistance.
7. Determination of overall heat transfer coefficient and efficiency in finned tube heat exchanger
8. Determination of overall heat transfer coefficient and efficiency in plate type heat exchanger
9. Determination of heat transfer coefficient in turbulent flow regime in a double pipe heat exchanger
10. Heat transfer from a pin fin (extended surfaces) – Determination of heat transfer coefficient and effectiveness of fin under forced and natural convection.

Design based Problems (DP)/Open Ended Problem:
Students are free to select from any area of heat transfer based on Environmental Engineering applications for defining projects.

1. Design and efficiency of various heat exchangers available in laboratory by different methods (LMTD and ε-NTU method).
2. Correlations of heat transfer coefficient and fanning friction factor as explained by different analogies in various diameter pipes.

Major Equipment: Emissivity apparatus, Metal rod apparatus, composite wall apparatus, lagged pipe apparatus, various heat exchange equipment like shell and tube heat exchanger, plate type heat exchanger etc.

ACTIVE LEARNING ASSIGNMENTS: Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus to be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide. The best three works should submit to GTU.